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(54) Intracavity probe and interface device for MRI imaging and spectroscopy.

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Description

Background of the Invention

The present invention relates to a receiving device for use in magnetic resonance imaging (MRI) and spectroscopy systems to enhance the imaging performance and spectroscopy sensitivity of such instruments when evaluating anatomical regions small in size relative to the body, and deep within the body, but proximate a location where an insertable pickup probe could be used. Specifically, the present invention relates to an intracavity pickup probe designed to image the prostate region by rectal introduction, to image the cervix region by vaginal introduction, or the like.

In the field of MRI systems, also commonly known as NMR imaging systems, external pickup probes are typically used for receiving radio frequency signals from the region of interest. For optimum performance however, the pickup probe should be insertable for intracavity use and which includes a radio frequency receiving coil, to be positioned as close to the region of interest as possible. In addition, the insertable pickup probe should also have a sensitive volume equaling the desired field of view of the region of interest. This allows optimization of the "filling factor" and "coupling coefficient" for the specific MRI system, thereby improving signal to noise ratio in MR imaging.

An insertable intracavity probe having the features defined in the first part of claim 1 is known from WO-A-86/01093.

Furthermore, for optimum sensitivity, the receiving coil should have an unloaded coil quality factor (Q) which is as great as possible and should be adjusted to resonate at the exact Larmour frequency of the scanner of the MRI system. It also sometimes is desired that the insertable, intracavity pickup probe be disposable, and hence the cost of the probe should be minimized as much as possible. At the same time, it is important that in reducing the cost of the probe, the ability to impedance match and tune the receiving coil to the scanner of the MRI system not be compromised. Therefore, there is a need to provide a disposable pickup probe at minimal cost for use in a MRI system which is capable of automatically or manually tuning and impedance matching the receiving coil to the scanner of the MRI system.

Summary of the Invention

It is a primary object of the present invention to provide an insertable MRI pickup probe and an interface network having the ability to match the coil of the pickup probe to the resonant frequency of an MRI scanner in an MRI system.

It is an additional object of the present invention to provide an insertable, intracavity pickup probe capable of being placed in close proximity to the region of interest to improve the quality of a magnetic resonance image or spectrum.

It is a further object of the present invention to provide an insertable MRI pickup probe and an interface system having the ability to perform resonant frequency adjustments from a remote location after the probe is inserted into the body of a patient.

It is yet another object of the present invention to provide an insertable MRI pickup probe having a receiving coil, and an interface network having the ability to automatically match the output impedance of the receiving coil with the input impedance of an MRI scanner after the probe is inserted into the body of the patient.

The present invention in its most specific embodiment relates to an insertable, intracavity pickup probe, and more specifically an intrarectal pickup probe and an associated interface network for high sensitivity and high resolution imaging of the male prostate gland and associated area. Although the pickup probe is described hereinafter as principally to image or obtain spectra from the area of the male prostate gland, it should be understood that the concepts outlined herein are equally appropriate for other regions of interest such as the rectum, vagina, and mouth. Additionally, the principles described herein may be applied to MRI or NMR applications involving the arteries, veins, and other similar regions of the body reachable by an insertable or implantable pickup probe.

The insertable pickup probe of the present invention greatly improves the signal-to-noise ratio of an image or spectrum acquisition over signal pickup devices commonly used with MRI and NMR scanner systems. In addition, the restricted field of view of the probe reduces or eliminates image distortion caused by motion, blood flow, patient breathing, and signal aliasing when conducting an image acquisition using multidimensional fast Fourier transform techniques.

The insertable pickup probe of the present invention comprises a shaft which supports an inflatable patient interface balloon at its distal end. In a specific embodiment, the interface balloon comprises an inner balloon and an outer balloon, between which a receiving coil is positioned. A lumen for air supply is provided in the shaft for expanding the inner balloon outwardly against the outer balloon to place the receiving coil in close proximity to the region of interest once the insertable pickup probe is inserted into the body of the patient. In the specific embodiment of the present invention, the pickup probe is a prostate probe and is designed

for insertion into the body intrarectally. An anti-migration disc is provided which fits onto the shaft of the probe to prevent migration of the probe superiorly during the normal peristaltic activity of the colon. Furthermore, an introducer is provided which surrounds the shaft and slides over the entire length of the shaft. The introducer functions as a dilator for the anal sphincter during insertion.

The insertable pickup probe of the present invention allows for accurate longitudinal and radial positioning of the balloon within the body by making the shaft rigid when twisted radially. The balloon, shaft and handle are bonded together so that they rotate as a single unit when torque is applied. The distal tip of the probe is more flexible than the shaft to avoid perforating tissue during use.

An inflater cuff is provided which connects to the shaft and functions as an air pump to deliver a volume-limited amount of air through the air lumen of the shaft to the inner balloon. Furthermore, a stop cock is provided to maintain the air within the inner balloon. The receiving coil extends through another lumen of the shaft and connects to an interconnecting cable which electrically connects the receiving coil to the interface network. Typically, the probe, with built-in balloon, receiving coil, inflator cuff and including the shaft, anti-migration disc, and introducer, is disposable.

The interface network in an embodiment of the present invention performs three functions in conjunction with the insertable pickup probe and a MRI or NMR scanner of an imaging system. First, the interface network tunes the receiving coil of the pickup probe to the Larmour frequency of the scanner. Second, the interface network matches the output impedance of the probe to the input impedance of the scanner. Third, the interface network decouples the receiving coil during the transmitting portion of a scanning sequence, if the probe is used as a receive only coil.

Tuning of the receiving coil to the Larmour frequency of the MRI scanner is accomplished manually or automatically. In the preferred embodiment, the interface network is an electronic optimization circuit to automatically adjust the resonance frequency seen at the output of the probe. In addition, in alternative versions, the interface network includes an electronic optimization circuit to allow automatic optimization of both the tuning and the impedance transformation ratio.

The above and other objects and advantages of the present invention will become more readily apparent when reference is made to the following description, taken in conjunction with the accompanying drawings.

Brief Description of the Drawings

Figure 1 is a perspective view illustrating the insertable pickup probe and the interface network in accordance with the present invention.

Figure 2 is a cross-sectional view taken through line 2-2 of the distal inflatable balloon portion of the insertable pickup probe illustrated in Figure 1.

Figure 3 is an end view as seen from line 3-3 of the insertable pickup probe illustrated in Figure 1.

Figure 4 is a sectional view taken through line 4-4 of Figure 2.

Figure 5 is a top sectional view as seen from line 5-5 of Figure 2.

Figure 6 is a schematic diagram illustrating the receiving coil and interconnecting cable of the insertable pickup probe of the present invention.

Figure 7 is a schematic diagram illustrating the interconnecting cable and receiving coil fabricated from a single piece of coaxial RF cable in accordance with the present invention.

Figure 8 is a cross-sectional view illustrating the shaft of the insertable pickup probe illustrated in Figure 1.

Figure 9 is a schematic diagram illustrating the circuit for performing impedance matching of the probe illustrated in Figure 1 with a remote MRI scanning system.

Figure 10 is a schematic diagram illustrating the circuitry in the interface network for automatically tuning the receiving coil to a specific frequency for a remote MRI scanner.

Figure 11 is a schematic diagram illustrating the circuitry of the interface network for manually or automatically tuning and impedance matching the receiving coil to a remote MRI scanner.

Detailed Description of the Drawings

Referring first to Figure 1, the insertable prostate pickup probe is shown in an assembled form at 10, which connects to an interface network 12. The insertable prostate pickup probe 10 is an MRI or NMR receiving device capable of imaging or gathering spectra from the human prostate and surrounding tissue, but may also be used as the transmit coil for RF excitation. The probe 10 is used with the interface network 12 which provides the tuning, impedance matching, and decoupling functions.

The probe 10 includes a shaft 14 which supports a patient interface balloon 16 at its distal end, an anti-migration disc 18, an introducer 20, and a handle 22 located at the proximal end of the shaft 14. An inflater cuff 24 is provided for supplying air to the patient interface balloon 16 and connects to

the proximal end of the shaft by a tube 26. A stop cock 28 is provided in the tube 26 for controlling the passage of air through the tube 26 to the patient interface balloon 16.

As will be described in more detail hereinafter, a receiving coil is contained within the patient interface balloon 16 and electrically connected to the interface 12 by an insulated interconnecting cable 30 which has a plug 32 at its proximal end for connection to terminal 34 located on the front of the interface network 12.

The interface network 12 also includes a terminal 36 for providing a connection to a MRI scanner. Furthermore, the interface network 12 includes a switch 38 capable of being moved between an operating position and a tuning position. To display to the operator the mode of operation, indicator lights 40 are provided on the front of the interface network 12. In addition, a light 42 for indicating the occurrence of a probe failure is provided on the front of the interface network 12.

Referring now to Figures 2, 4, 5, and 8, the patient interface balloon 16 of the insertable pickup probe 10 is illustrated in more detail. The patient interface balloon 16 comprises an inner balloon 44 and an outer balloon 46. The inner balloon 44 is constructed of a flexible medical grade latex or other elastomeric material, which is preferably non-paramagnetic and has low dielectric losses, and is capable of being inflated with air supplied through a lumen 48 within the shaft 14, and expelled into the inner balloon 44 via a hole 49 in lumen 48. The inner balloon 44 is substantially cylindrical in shape except for an anterior flat plane which is covered with a non-stretchable material plane 50, formed of, for example, an adhesive backed cloth material.

A receiving coil 52 is provided between the inner balloon 44 and the outer balloon 46 and is typically formed of a flexible conductive material. The receiving coil 52 is arranged between the non-stretchable plane 50 and the outer balloon 46, is fed to the patient interface balloon 16 through a second lumen 54 in the shaft 14, and is fed out of the shaft 14 through a hole 56 in the shaft 14 inside the outer balloon 46.

The outer balloon 46 has an anterior saddle shape as indicated at reference number 62, for conformably fitting the rectal prostatic bulge inferior to the ampulla of the rectum. In addition, the outer balloon 46 has posterior undulating folds 64 which allow the patient interface balloon 16 to unfold first when the inner balloon 44 is inflated. This unfolding forces the anterior surface 62 to hug the prostatic region of the rectum, thereby ensuring that the image field of view of the insertable pickup probe 10 will focus on the desired region of interest.

The non-stretchable plane 50 serves two functions in the patient interface balloon 16. First, the plane 50 controls the focus of the inflation stretch of the inner balloon 44; secondly, plane 50 acts as a guide for the receiving coil 52. Upon inflation, the inner balloon 44 first stretches posteriorly away from the receiving coil 52. This initiates the folds 64 of the outer balloon 46 to force posteriorly against the rectum wall until the anatomy offers an equal resistance. Then, the non-stretchable plane 50 rises and forces the receiving coil 52 and the anterior surface 62 of the outer balloon 46 against the region of interest. When inflation is complete, the receiving coil 52 is in position to receive the best possible RF signal from the region of interest.

In addition, as shown in Figure 4, lateral indentations 74 are provided on the outer balloon 46. The indentations 74 act as coil positioners when the balloon is in its uninflated state. The receiving coil 52 is positioned on the shelf formed by the indentations 74 during assembly of the probe. This allows the receiving coil 52 to be repeatedly positioned relative to the shelf inside the outer balloon 46 for numerous clinical inflation and deflation cycles.

Alternatively, the patient interface balloon 16 may be constructed with a single ply inflatable balloon of elastomeric material. In this arrangement, the receiving coil 52 would be bonded to the inside surface of the balloon.

Further yet, the interface balloon 16 may be constructed with a single multi-ply balloon. This balloon would have the receiving coil 52 encapsulated between the plies of the elastomeric material. When inflated, the receiving coil 52 would be forced against the region of interest by the movement of the balloon. The coil encapsulation would take place during the balloon fabrication process by placing the receiving coil 52 on the surface of the balloon and then redipping the balloon to place another ply of material over the outer surface of the balloon, thus covering the receiving coil 52.

To assist a clinician in the insertion of the pickup probe 10, a colored stripe 55 is painted or otherwise marked on the shaft 14. The stripe 55, best shown in Figure 1, and also shown in Figure 8, may include a scale for indicating the distance which the shaft 14 has been inserted into the patient, and also the radial orientation of the balloon 16 for proper alignment with the prostate. In addition, the distal end 15 (hereinafter referred to as the flexible tip), of the shaft 14 which fits into the balloon 16 is typically more flexible than the remaining length of the shaft 14 to provide a more comfortable fit in the patient and to reduce the possibility of perforating tissue during use.

Referring to Figures 1, 2 and 8, the shaft 14 is rigid so that when it is twisted radially at the handle 22, the balloon, shaft, and handle move as a unit to ensure alignment. The flexible tip 15 is typically

made of a more flexible material than the shaft 14, and is bonded to the shaft 14 as indicated at reference numeral 17. The outer balloon 62 is anchored to the shaft 14 by a proximal clamp 60 and by an interference fit with the flexible tip 15 of the shaft 14. Similarly, the inner balloon 44 is anchored to the shaft 74 by a proximal clamp 58 and by an interference fit with the flexible tip 15.

Figure 3 illustrates the anti-migration disc 18 in more detail as it fits onto the shaft 14. The disc 18 is semi-spherical and constructed from semi-rigid plastic. The purpose of the anti-migration disc 18 is to prevent the pickup probe 10 from migrating superiorly due to the normal peristaltic activity of the colon. The disc 18 has a slot 19 which snaps onto the shaft, as shown in Figure 3, adjacent the anal sphincter after the device has been operatively placed within the patient.

Turning now to Figures 6 and 7, the connection of the receiving coil 52 to the insulated interconnecting cable 30 will be described in more detail. The receiving coil 52 is a flexible single turn coil capable of picking up radio frequency (RF) signals. In the preferred embodiment, as mentioned previously, the inner balloon 44 of the patient interface balloon 16 displaces the receiving coil 52 to the inside of the anterior surface of the outer balloon 46 upon probe inflation. This optimizes the coupling between the coil 52 and the target anatomy. In order to minimize the dielectric losses in the probe-patient interaction, the receiving coil 52 is surrounded by a Faraday shield 66 to confine the majority of the coil electrostatic field within a coil-shield gap 68. Since the signal coupling from the NMR proton spin systems to the receiving coil 52 is achieved exclusively by magnetic means, the presence of the Faraday shield 66 will not detract from the NMR signal, as it is essentially transparent to magnetic field interaction.

The reduction of electrostatic field interaction between the patient and the probe will provide two benefits. First, there will be a reduced electrostatic loss, and thus a greater coil quality factor Q. Second, the effects of the specifics of a particular patient on coil tuning will be reduced due to the containment of the electrostatic field to a defined region. The use of the Faraday shielded coil design will also improve the signal-to-noise ratio performance of the coil 52 by raising the coil Q. In general, the signal to noise ratio of two geometrically equivalent coils is proportional to the square root of the loaded coil Q, as long as the apparent Q occurs only from the current flowing in the resonant path including the coil conductor.

The receiving coil 52 of the present invention, in its preferred form, is operated in a series resonant mode, and the interconnecting cable 30 is used as a resonant transformer to convert the probe impedance from a series resonance type to a parallel resonant one as seen at the plug 32 of the interconnecting cable 30. Typically, the interconnecting cable 30 is a coaxial cable. As illustrated in Figure 7, the receiving coil 52 is resonated by a series capacitor 70. The length of the cable 30 is one quarter wavelength which allows remote tuning of the receiving coil with one half as much loss in the cable 30 in the series resonant configuration, rather than a parallel resonant configuration, which would employ a one half wavelength cable to connect the coil to the interface network 12. Use of the one quarter wavelength cable also simplifies the decoupling of the receiving coil 52, as will be described hereinafter.

As mentioned above, the connection of the pickup probe 10 to the interface network 12 is accomplished with a one quarter wavelength cable 30. In the preferred embodiment, the receiving coil 52 and the conductive portion of the cable 30 are fabricated from a single piece of coaxial RF cable as illustrated in Figure 7. The interconnecting cable 30 serves two system functions. First, in the signal acquisition mode (receive mode), the cable transforms the series resonant coil to appear as a parallel resonant device, according to the well known relationship: $Z_{output} = (Z_{cable})(Z_{cable})/Z_{input}$ where Z_{ouput} is the probe impedance as seen at the interface network 12, Z_{cable} is the characteristic impedance of the cable 30 also used to construct the coil 52, and Z_{input} is the series resonant impedance of the receiving coil 52 itself.

As will be described in more detail hereinafter, in the transmitting mode, when the coil 52 is to be decoupled, Z_{output} is the resistance placed in series with the resonant path of the receiving coil 52 itself. Z_{cable} is the characteristic impedance of the coaxial cable used to construct the receiving coil 52 and cable 30, and Z_{input} is the RF resistance of the PIN diode or crossed diodes (illustrated in Figure 9) when forward biased in the transmit mode.

In operation, the probe 10 is inserted intrarectally while the patient interface balloon 16 is in the uninflated relaxed state. The provided alignment guide 55 is used to radially and longitudinally position the probe 10 within or adjacent the region of interest. The patient interface balloon 16 is then inflated via the inflator cuff 24 to optimize the tissue to probe interface. The anti-migration disc 18 is then used to maintain proper positioning of the pickup probe 10 during the clinical scanning procedure. During insertion, the introducer 20 functions as a dilator for the anal sphincter. The funnel shaped introducer 20 slides easily over the entire length of the shaft 14. Without the introducer, the anal sphincter would contract around the shaft and interfere with the ability to radially and longitudinally position the pickup probe 10. Thus, the intro-

ducer 20 immediately follows the patient interface balloon 16 to prevent the anal sphincter from contracting around the shaft 14 of the pickup probe 10. The clinician can then have free movement of the probe 10 in the rectal cavity. Once the probe 10 is correctly placed, the introducer 20 is pulled inferiorly along the shaft 14, allowing the sphincter to contract around the shaft 14. This contraction assists in holding the probe 10 in place.

Once the patient interface balloon 16 is inflated, the stop cock 28 is moved to a closed position, thus allowing the clinician to disconnect the inflater cuff 24 without deflating the interface balloon 16. The probe 10 is then connected to the interface network 12 via plug 32 of the cable 30.

Referring now to Figures 9-11, the interface network 12 will be described in detail as it is used with the insertable pickup probe 10 and a MRI or NMR scanner 73. The interface network 10 serves three purposes: tuning of the receiving coil 52 of the probe 10 to the Larmour frequency of the MRI or NMR scanner 73; transforming of the output impedance of the probe 10 to match the scanner input impedance, which is typically 50 ohms; and, decoupling of the probe 10 during the transmit portion of the scanning sequence. Tuning may be accomplished manually or automatically. In the preferred embodiment, an electronic optimization circuit is provided to automatically adjust the resonance of the probe 10.

The receiving coil 52 of the probe 10 is series resonant and includes a transformer in the form of the one quarter wavelength cable 30 to convert the series resonance to a parallel resonance. The frequency of resonance may be altered by placing an appropriate reactance between the scanner 73 and the interconnecting cable 30, remote from the probe 10 itself. As such, the probe 10 may be tuned to the scanner 73 after the probe is inserted into the patient.

As shown in Figure 9, the interface 12 includes a conventional Pi network 72 consisting of a single series inductor L, and shunting capacitors C_{tune} and C_{match}, at each end of the network 72. To facilitate tuning of the probe 10, the input capacitor C_{tune} of the Pi network 72 is made variable as illustrated. Thus, by changing the value of this capacitor, either manually, or automatically by electronically changing the voltage across a varactor diode which may be substituted for the capacitor C_{tune}, the net reactance appearing across the output of the cable 30 from the probe 10 is adjusted. Since some of the reactance of the capacitor C_{tune} is absorbed into the Pi network 72, the apparent reactance presented to the probe output can appear resistive, capacitively reactive, or inductively reactive. This allows the probe to be tuned both above and below its natural resonant frequency, while limiting the level of circulating resonance current in the interconnecting cable 30 to the lowest possible value (ideally zero in the case where the natural resonance of the insertable pickup probe matches the Larmour frequency of the MRI or NMR scanner).

For automatic tuning of the probe 10, the control voltage for the varactor diode substituted for the capacitor C_{tune} in the Pi network 72, is obtained from an electronic tuning circuit described hereinafter. Under manual tuning, the operator simply adjusts the variable capacitor C_{tune} to reduce the S11 parameter of the receiving coil 52 as seen at the output port 36 of the interface network 12, to the minimum value. As is well known in the art, the S11 parameter is the scattering parameter of standard RF measurements which indicates the ratio of reflected to incident power at the input port of a network. When the reflected power is 0, representing a voltage standing wave ratio (VSWR) of 1.0:1, the S11 parameter is also 0. When the VSWR is infinite, representing all the incident power being reflected at the input port, the S11 parameter is 1.0.

To match the impedance of the probe 10 to the scanner 73, transformation of the real part of the output impedance (in the range of 1,000 to 1,500 ohms in the preferred embodiment at 64 MHz) of the probe 10 is accomplished with the Pi network 72 of Figure 9. Any impedance matching network design could be used in place of the Pi network 72 illustrated in Figure 9. The values of the various components comprising the Pi network 72 are chosen to match the impedances of the probe 10 and scanner 73.

During the transmitting portion of the scanning procedure, the probe 10 must be decoupled from the MRI scanner 73 to prevent distortion of the transmitted magnetic field. This is accomplished by the use of an RF switch at the probe input terminal 34 of the interface network 12. A PIN diode 74 or crossed RF switching diodes can be used at this location, as illustrated in Figure 9, to create a very low impedance at the resonant frequency of the probe 10 during transmit excitation. Because of the impedance transforming capability provided by the one quarter wavelength cable 32, the PIN diode 74 is forward biased with exceptionally low RF resistance to appear as an open circuit in series with the receiving coil 52. This limits the RF current flow within the receiving coil 52 to a very low value, and effectively decouples the receiving coil 52 from the incident RF magnetic excitation field transmitted into the patient. This arrangement allows the decoupling diode switch 74 to be located remote from the probe 10, and can be reused as part of the interface network 12 after the probe 10 is disposed.

Referring now to Figure 10, the circuitry for accomplishing the automatic tuning of the receiving

coil 52 of the probe 10 is generally shown at 76. This circuitry is incorporated within the interface network 12 and operates by sampling the S11 parameter of the probe 10 and Pi network 72, to generate a control voltage for tuning the probe 10 with the varactor diode, substituted for C_{tune}, at the probe input terminal 34 of the interface network 12, and a circuit to lock the control voltage at the value which optimizes the S11 parameter. The value of the S11 parameter is determined by using a local signal source 78 to replace the scanner output terminal 36 on the interface network 12 during the tuning procedure as accomplished by the switch 38 of the interface network 12. A directional coupler 80, connected to the local signal source 78 obtains a sample of the reflected power from the signal source when using the probe 10 and the interface network 12 as a load. This sample is fed to an amplifier 82 and converted to a DC level. The resulting DC signal is then fed into a slope detector 86 of either analog or digital design.

The slope detector 86, for example, may comprise a RF detector 84 and an analog to digital converter 88 connected to a latch circuit 90 and a digital comparator 92. The analog to digital converter 88 is also connected, together with the latch circuit 90 and the digital comparator 92 to a sequencer 94. The digital comparator 92 provides an output stop command signal to a clock circuit 96 which controls the contents of a counter 98. The value within the counter 98 determines the value of the control voltage to be applied to the varactor diode which is converted from a digital signal to an analog signal by the digital to analog converter 100.

In general terms, the slope detector 86 determines the minimum point of a function, which function in this case is the ratio of reflected to incident power (the S11 parameter). This function monotonically increases in both directions from the minimum point. As the tuning is swept, the function is dropped until a minimum is reached, and then begins to increase again.

The digital slope detector 86 compares the digitized voltage level of a present data point of the function, with the previous data point. When it is found that the present data point is equal to or greater than the previous point, a level shift from logic 0 to logic 1 is output. The control voltage produced at the output of the digital to analog converter 100 is ramped from a minimum value towards a maximum value. When the DC level representing the S11 parameter reaches zero slope as it drops from a starting value, the varactor control voltage is locked to the value at that point.

Alternatively, the slope detector may be of an analog design comprising an operational amplifier-differentiator circuit. This circuit takes the first derivative of the voltage level. As the first derivative or slope reverses direction, the operational amplifier output ramps rapidly from its negative rail voltage towards its positive rail voltage. This occurrence can be used as a stop pulse to indicate the minimum.

The slope detector circuit 86 can also be used to indicate probe failure. This is accomplished in two ways. First, the tuning of the S11 function never crosses a minimum, or secondly, if the absolute value of the tuning function (S11) becomes greater than a predetermined maximum acceptable value at the minimum. The first condition is an indication of a non-resonant probe, either due to component tolerance, failure, or improper construction. The second condition reveals a probe with an excessively low or high Q, typically indicative of improper construction or faulty materials.

Manual tuning can be accomplished by the circuit illustrated in Figure 11 and generally shown at 102. All of the elements of circuit 102 are similar to that of circuit 76 with the exception of the digital voltmeter 104 substituted for the slope detector circuit 86. The reflected power during the tuning procedure is displayed as a scaler quantity on the digital voltmeter 104 to provide information to the operator relating to the status of the probe tuning. The capacitance of the capacitor C_{tune} is manually varied during this procedure to minimize the reflected power.

Alternatively, in the event that the probe system requires the ability to automatically control the impedance matching as well as tuning, a second varactor illustrated as C_{match} in Figure 11, may be employed as the output capacitor of the Pi network 72. Adjustment of this reactance in an iterative fashion together with the adjustment of the tuning capacitor C_{tune} may be accomplished by the automatic tuning circuit illustrated in Figure 10 by toggling the optimization function between the two capacitors.

The interface network 12 enjoys the benefits of placing all of the decoupling, tuning, and impedance matching hardware remote from the probe 10 itself to make the probe 10 compatible with MRI and NMR scanners of different designs by modifying only the interface network 12 and not the probe 10. Thus, all systems operating at any specific frequency, such as the various 1.5 Tesla systems, could be accommodated by a single probe type; the variations in the system interface requirements such as the decoupling method (active or passive), connector type, input impedance, and the like could be accommodated by system-specific interface designs. In addition, the interface network 12 can be designed to be applicable to a family of probes of similar designs.

The above description is intended by way of example only and is not intended to limit the present invention in any way except as set forth in the following claims.

Claims

1. An insertable intracavity probe for use in a magnetic resonance system for obtaining images or spectra of a region of interest within a cavity of a patient, said probe (10) comprising:
   a) an elongated shaft member (14) having proximal and distal ends,
   b) a receiving coil (52) positioned proximate the distal end of said shaft member (14), and
   c) an interconnecting cable (30) connected to said receiving coil (52) for providing electrical connection to said flexible coil (52),
   characterized therein,
   d) an inflatable interface balloon means (16) including at least one balloon is positioned proximate the distal end of said shaft member (14),
   e) said receiving coil (52) is flexible and contained within said inflatable interface balloon means (16),
   f) said inflatable interface balloon means (16) is uninflated during insertion of said probe (10) into said cavity,
   g) inflating means connected to said interface balloon means (16) for inflating said interface balloon means (16) and displacing said receiving coil (52) upon inflation, and
   h) when inflation is complete, said receiving coil (52) is in a position to receive signals from the region of interest.

2. An insertable intracavity probe according to claim 1,
   characterized therein,
   said inflatable interface balloon means (16) comprising an inflatable inner balloon (44) and a flexibel outer balloon (46) enclosing said inner balloon (44).

3. An insertable intracavity probe according to claim 2,
   characterized therein,
   said receiving coil (52) is positioned between said inner balloon (44) and said outer balloon (46).

4. An insertable intracavity probe according to claim 1,
   characterized therein,
   said interface balloon means (16) includes a single multi-ply inflatable balloon, and said receiving coil (52) is encapsulated between the plies of said balloon.

5. An insertable intracavity probe according to claim 1,
   characterized therein,
   said interface balloon means (16) includes a single ply inflatable balloon and said receiving coil (52) is bonded to the inside surface of said balloon.

6. An insertable intracavity probe according to anyone of the claims 1 to 5,
   characterized therein,
   said interface balloon means (16) is planar and having posterior undulating folds (64), and said undulating folds (64) of the inflated interface balloon means (16) are forced against a wall of said cavity generally opposite the region of interest to secure said balloon adjacent to the region of interest.

7. An insertable intracavity probe according to anyone of the claims 1 to 6,
   characterized therein,
   said receiving coil (52) is electrically coupled to a remote scanning device.

8. An insertable intracavity probe according to claims 1 to 7,
   characterized therein,
   said inflatable interface balloon means (16) includes elastomeric material.

9. An insertable intracavity probe according to anyone of the claims 1 to 8,
   characterized therein,
   said interface balloon means (16) includes a non-stretchable member (50) for positioning said receiving coil (52) in said interface balloon means (16).

10. An insertable intracavity probe according to anyone of the claims 1 to 9,
    characterized therein,
    said elongated shaft member (14) having at least one lumen, said inflating means (24) is connected to said shaft member (14) and connected to said inflatable interface balloon means (16) via said lumen of said shaft member (14); and
    said interconnecting cable (30) is connected to said shaft member (14) for providing electrical connection to said flexible coil (52) via said lumen of said shaft member (14).

11. An insertable intracavity probe according to anyone of claims 1 to 10,

characterized therein,
said elongated shaft member (14) includes first (48) and second (54) lumens, said inflating means is connected to said inflatable balloon via said first lumen (48) of said shaft member (14); and
said interconnecting cable (30) is connected to said flexible coil (52) via said second lumen (54) of said shaft member (14).

12. An insertable intracavity probe according to anyone of claims 9 to 11,
characterized therein,
said non-stretchable member (50) is attached to the surface of said inner balloon (44) adjacent said coil (52).

13. An insertable intracavity probe according to claims 11 or 12,
characterized therein,
said inflating means comprises a compressible inflator cuff (24) and a tube (26) connected to said shaft member (14) to deliver air upon compression of said cuff (24) to said inner balloon (44) via said first lumen (48) of said shaft member (14), and further including a stop cock (28) on the tube (26) connecting said inflating cuff (24) to said shaft member (14), said stop cock (28) maintaining said inner balloon (44) in an inflated state when placed in a closed position.

14. An insertable intracavity probe according to anyone of claims 1 to 13,
characterized therein
said flexible coil (52) is a series resonant coil, and said interconnecting cable (30) is a one quarter wavelength cable which transforms the series resonant coil to a parallel resonant coil as seen at the proximal end of the cable.

15. An insertable intracavity probe according to anyone of claims 2 to 14,
characterized therein,
said outer balloon (46) comprises an anterior saddle shape (62) on one surface thereof and lateral indentations (74) on each side of said outer balloon (46); and
said flexible coil (52) contained within said interface balloon means (16) between said inner balloon (44) and said outer balloon (46) is maintained in position in said interface balloon means (16) by said lateral indentations (74) of said outer balloon (46).

16. An insertable intracavity probe according to anyone of the claims 10 to 15,
characterized therein,
said flexible coil (52) and said interconnecting cable (30) are formed of a single piece of RF coaxial cable;
said inflating means (24) is connected to said shaft member (14) and connected to said inflatable interface balloon means (16) via said lumen of said shaft member (14); and
said interconnecting cable (30) is connected to said shaft member (14) for providing electrical connection to said flexible coil (52) via said lumen of said shaft member (14).

17. An insertable intracavity probe according to anyone of the preceding claims,
characterized therein,
said elongated shaft member (14) comprises a rigid elongated portion and a flexible distal tip portion (15).

18. An insertable intracavity probe according to anyone of the preceding claims,
characterized therein,
further comprising a handle (22) at the proximal end of said shaft member (14), wherein said shaft member (14), said interface balloon means (16), and said handle (22) are bonded together to rotate as a single unit when torque is applied at said handle (22).

19. An insertable intracavity probe according to anyone of the preceding claims,
characterized therein,
further including alignment marker means on said shaft member (14) to indicate the relative longitudinal and radial position of said shaft member (14) when inserted into a patient.

20. An insertable intracavity probe according to anyone of the preceding claims,
characterized therein,
said shaft member (14) includes a positioning scale printed on the outer surface thereof.

21. An insertable intracavity probe according to anyone of the preceding claims,
characterized therein,
comprising an anti-migration disc (18), said anti-migration disc (18) having a semi-spherical shape and a slot which snaps into said shaft member (14) for preventing unwanted movement of said probe (10) relative to the cavity of the patient.

22. An insertable intracavity probe according to anyone of the preceding claims,
characterized therein,
comprising a dilator element slidably mounted on said shaft member (14) for dilating an ori-

fice leading to said cavity to allow easy positioning of the probe (10) within the cavity.

Patentansprüche

1. Einführbare Körperhöhlensonde zur Verwendung in einem magnetischen Resonanzsystem zur Erlangung von Bildern oder Spektren einer Region von Interesse innerhalb einer Körperhöhle eines Patienten, wobei die Sonde (10) umfaßt:
   a) ein längliches Schaftelement (14) mit einem proximalen und einem distalen Ende,
   b) eine Empfangsspule (52), welche in der Nähe des distalen Endes des Schaftelementes (14) angeordnet ist und
   c) eine Verbindungsleitung (30), welche mit der Empfangsspule (52) zur Schaffung einer elektrischen Verbindung zur flexiblen Spule (52) verbunden ist,
   dadurch **gekennzeichnet,**
   d) daß ein aufblasbarer Interface-Ballon (16) mit wenigstens einem Ballon in der Nähe des distalen Endes des Schaftelementes (14) angeordnet ist,
   e) daß die Empfangsspule (52) flexibel und in dem aufblasbaren Interface-Ballon (16) enthalten ist,
   f) daß der aufblasbare Interface-Ballon (16) während des Einführens der Sonde (10) in die Körperhöhle nicht aufgeblasen ist,
   g) daß eine Aufblaseinrichtung mit dem Interface-Ballon (16) zum Aufblasen des Interface-Ballons (16) und zum Verschieben der Empfangsspule (52) aufgrund des Aufblasens verbunden ist, und
   h) daß die Empfangsspule (52) sich in einer Position zum Empfangen von Signalen aus der Region von Interesse befindet, wenn das Aufblasen abgeschlossen ist.

2. Einführbare Körperhöhlensonde nach Anspruch 1,
   dadurch **gekennzeichnet,**
   daß der aufblasbare Interface-Ballon (16) einen aufblasbaren inneren Ballon (44) und einen flexiblen äußeren Ballon (46) aufweist, welcher den inneren Ballon (44) umschließt.

3. Einführbare Körperhöhlensonde nach Anspruch 2,
   dadurch **gekennzeichnet,**
   daß die Empfangsspule (52) zwischen dem inneren Ballon (44) und dem äußeren Ballon (46) angeordnet ist.

4. Einführbare Körperhöhlensonde nach Anspruch 1,
   dadurch **gekennzeichnet,**
   daß der Interface-Ballon (16) einen einzelnen aufblasbaren Mehrschichtballon aufweist und daß die Empfangsspule (52) zwischen den Schichten des Ballons eingeschlossen ist.

5. Einführbare Körperhöhlensonde nach Anspruch 1,
   dadurch **gekennzeichnet,**
   daß der Interface-Ballon (16) einen aufblasbaren Einschichtballon aufweist und daß die Empfangsspule (52) mit der Innenseite des Ballons verbunden ist.

6. Einführbare Körperhöhlensonde nach einem der Ansprüche 1 bis 5,
   dadurch **gekennzeichnet,**
   daß der Interface-Ballon (16) flach ist und mit hinteren wellenförmigen Falten (64) ausgebildet ist und daß zur Lagesicherung des Ballons angrenzend an die Region von Interesse die wellenförmigen Falten (64) des aufgeblasenen Interface-Ballons (16) gegen eine Wand der Körperhöhle gepreßt sind, welche im allgemeinen gegenüber der Region von Interesse liegt.

7. Einführbare Körperhöhlensonde nach einem der Ansprüche 1 bis 6,
   dadurch **gekennzeichnet,**
   daß die Empfangsspule (52) elektrisch mit einer rückwärtigen Abtastvorrichtung in Verbindung steht.

8. Einführbare Körperhöhlensonde nach einem der Ansprüche 1 bis 7,
   dadurch **gekennzeichnet,**
   daß der aufblasbare Interface-Ballon (16) ein Elastomermaterial aufweist.

9. Einführbare Körperhöhlensonde nach einem der Ansprüche 1 bis 8,
   dadurch **gekennzeichnet,**
   daß der Interface-Ballon (16) ein nicht dehnbares Element (50) zum Positionieren der Empfangsspule (52) in dem Interface-Ballon (16) aufweist.

10. Einführbare Körperhöhlensonde nach einem der Ansprüche 1 bis 9,
    dadurch **gekennzeichnet,**
    daß das längliche Schaftelement (14) wenigstens einen Hohlraum aufweist, wobei die Aufblaseinrichtung (24) mit dem Schaftelement (14) und über den Hohlraum des Schaftelementes (14) mit dem aufblasbaren Interface-Ballon (16) verbunden ist, und
    daß die Verbindungsleitung (30) mit dem Schaftelement (14) zur Schaffung einer elektri-

schen Verbindung zu der flexiblen Spule (52) über den Hohlraum des Schaftelementes (14) verbunden ist.

11. Einführbare Körperhöhlensonde nach einem der Ansprüche 1 bis 10, dadurch **gekennzeichnet**, daß das längliche Schaftelement (14) einen ersten (48) und einen zweiten (54) Hohlraum aufweist, wobei die Aufblaseinrichtung über den ersten Hohlraum (48) des Schaftelementes (14) mit dem aufblasbaren Ballon verbunden ist, und daß die Verbindungsleitung (30) über den zweiten Hohlraum (54) des Schaftelementes (14) mit der flexiblen Spule (52) verbunden ist.

12. Einführbare Körperhöhlensonde nach einem der Ansprüche 9 bis 11, dadurch **gekennzeichnet**, daß das nicht dehnbare Element (50) an der Fläche des inneren Ballons (44) in der Nähe der Spule (52) befestigt ist.

13. Einführbare Körperhöhlensonde nach Anspruch 11 oder 12, dadurch **gekennzeichnet**, daß die Aufblaseinrichtung einen kompressiblen Blasebalg (24) und einen Schlauch (26) aufweist, welcher mit dem Schaftelement (14) verbunden ist, um über den ersten Hohlraum (48) des Schaftelementes (14) Luft durch Kompression des Balgs (24) zu dem inneren Ballon (44) zu leiten, und daß weiterhin ein Absperrhahn (28) an der Röhre (26) vorgesehen ist, welcher den Blasebalg (24) mit dem Schaftelement (14) verbindet, wobei der Absperrhahn (28) den inneren Ballon (44) in einem aufgeblasenen Zustand hält, wenn sich dieser in einer eng anliegenden Position befindet.

14. Einführbare Körperhöhlensonde nach einem der Ansprüche 1 bis 13, dadurch **gekennzeichnet**, daß die flexible Spule (52) eine Reihen-Resonanzspule ist und daß die Verbindungsleitung (30) eine ViertelwellenlängenLeitung ist, welche die Reihen-Resonanzspule zu einer Parallel-Resonanzspule umformt, wie sich diese an dem proximalen Ende der Leitung zeigt.

15. Einführbare Körperhöhlensonde nach einem der Ansprüche 2 bis 14, dadurch **gekennzeichnet**, daß der äußere Ballon (46) an seiner einen Oberfläche die Form eines vorderen Sattels (62) und seitliche Vertiefungen (74) an jeder Seite des äußeren Ballons (46) aufweist und daß die flexible Spule (52), welche innerhalb des Interface-Ballons (16) zwischen dem inneren Ballon (44) und dem äußeren Ballon (46) angeordnet ist, durch die seitlichen Vertiefungen (74) des äußeren Ballons (46) in dem Interface-Ballon (16) in Position gehalten ist.

16. Einführbare Körperhöhlensonde nach einem der Ansprüche 10 bis 15, dadurch **gekennzeichnet**, daß die flexible Spule (52) und die Verbindungsleitung (30) aus einem einzigen Stück eines RF-Koaxialkabels gebildet sind, daß die Aufblaseinrichtung (24) mit dem Schaftelement (14) und über den Hohlraum des Schaftelementes (14) mit dem aufblasbaren Interface-Ballon (16) verbunden ist und daß die Verbindungsleitung (30) mit dem Schaftelement (14) zur Schaffung einer elektrischen Verbindung über den Hohlraum des Schaftelementes (14) mit der flexiblen Spule (52) verbunden ist.

17. Einführbare Körperhöhlensonde nach einem der vorhergehenden Ansprüche, dadurch **gekennzeichnet**, daß das längliche Schaftelement (14) einen starren länglichen Abschnitt und eine flexible distale Spitze (15) aufweist.

18. Einführbare Körperhöhlensonde nach einem der vorhergehenden Ansprüche, dadurch **gekennzeichnet**, daß weiterhin ein Griff (22) an dem proximalen Ende des Schaftelementes (14) vorgesehen ist, wobei das Schaftelement (14), der Interface-Ballon (16) und der Griff (22) miteinander verbunden sind, um als eine Einheit gedreht zu werden, wenn ein Drehmoment an den Griff (22) angelegt wird.

19. Einführbare Körperhöhlensonde nach einem der vorhergehenden Ansprüche, dadurch **gekennzeichnet**, daß weiterhin eine Markierungsausrichtungseinrichtung an dem Schaftelement (14) vorgesehen ist, um die relative Länge und die radiale Position des Schaftelementes (14) anzuzeigen, wenn dieses in einen Patienten eingeführt ist.

20. Einführbare Körperhöhlensonde nach einem der vorhergehenden Ansprüche, dadurch **gekennzeichnet**, daß das Schaftelement (14) eine Positionierskala aufweist, welche an dessen äußerer Ober-

fläche aufgedruckt ist.

21. Einführbare Körperhöhlensonde nach einem der vorhergehenden Ansprüche, dadurch **gekennzeichnet**, daß eine Anti-Verschiebungsscheibe (18) vorgesehen ist, wobei die Anti-Verschiebungsscheibe (18) eine halbkugelförmige Ausformung und eine Nut aufweist, welche in das Schaftelement (14) einrastet, um eine unerwünschte Bewegung der Sonde (10) relativ zu der Körperhöhle des Patienten zu verhindern.

22. Einführbare Körperhöhlensonde nach einem der vorhergehenden Ansprüche, dadurch **gekennzeichnet**, daß ein Dehnelement vorgesehen ist, welches gleitend auf dem Schaftelement (14) gelagert ist, um eine Öffnung zu dehnen, welche zu der Körperhöhle führt, um eine einfache Positionierung der Sonde (10) innerhalb der Körperhöhle zu ermöglichen.

Revendications

1. Sonde intracavitaire introductible pour utilisation dans un système à résonance magnétique pour obtenir des images ou des spectres d'une région à examiner à l'intérieur d'une cavité d'un patient, ladite sonde (10) comprenant:
   a) un organe allongé en forme de tige (14) ayant des extrémités proximale et distale;
   b) une bobine réceptrice (52) disposée à proximité de l'extrémité distale dudit organe en forme de tige (14); et
   c) un câble d'interconnexion (30) connecté à ladite bobine réceptrice (52) pour réaliser une connexion électrique à ladite bobine flexible (52),
   caractérisé en ce que:
   d) un moyen formant ballonnet d'interface gonflable (16) comprenant au moins un ballonnet est disposé à proximité de l'extrémité distale dudit organe en forme de tige (14);
   e) ladite bobine réceptrice (52) est flexible et contenue dans ledit moyen formant ballonnet d'interface gonflable (16);
   f) le dit moyen formant ballonnet d'interface gonflable (16) est dégonflé pendant l'introduction de ladite sonde (10) dans ladite cavité;
   g) des moyens de gonflage connecté audit moyen formant ballonnet d'interface (16) pour gonfler ledit moyen formant ballonnet d'interface (16) et déplacer ladite bobine réceptrice (52) lors du gonflage; et
   h) lorsque le gonflage est terminé, ladite bobine réceptrice (52) est dans une position prévue pour recevoir des signaux issus de la région à examiner.

2. Sonde intracavitaire introductible selon la revendication 1,
   caractérisée en ce que:
   - ledit moyen formant ballonnet d'interface gonflable (16) comprend un ballonnet intérieur gonflable (44) et un ballonnet extérieur flexible (46) entourant complètement ledit ballonnet intérieur (44).

3. Sonde intracavitaire introductible selon la revendication 2,
   caractérisée en ce que;
   - ladite bobine réceptrice (52) est disposée entre ledit ballonnet intérieur (44) et ledit ballonnet extérieur (46).

4. Sonde intracavitaire introductible selon la revendication 1,
   caractérisée en ce que:
   - ledit moyen formant ballonnet d'interface (16) comprend un seul ballonnet gonflable multicouche, et ladite bobine réceptrice (52) est encapsulée entre les couches dudit ballonnet.

5. Sonde intracavitaire introductible selon la revendication 1,
   caractérisée en ce que:
   - ledit moyen formant ballonnet d'interface (16) comprend un ballonnet gonflable à une seule couche, et ladite bobine réceptrice (52) est collée à la surface intérieure dudit ballonnet.

6. Sonde intracavitaire introductible selon l'une quelconque des revendications 1 à 5,
   caractérisée en ce que:
   - ledit moyen formant ballonnet d'interface (16) est de forme plane et ont des plis ondulants postérieurs (64), et lesdits plis ondulants (64) du moyen formant ballonnet d'interface (16) sont forcés contre une paroi de ladite cavité opposée d'une manière générale à la région à examiner pour maintenir en place ledit ballonnet en position contigue à la région à examiner.

7. Sonde intracavitaire introductible selon l'une quelconque des revendications 1 à 6,
   caractérisée en ce que:
   - ladite bobine réceptrice (52) est reliée électriquement à un dispositif à balayage situé à distance.

8. Sonde intracavitaire introductible selon les revendications 1 à 7,
caractérisée en ce que:
- ledit moyen formant ballonnet d'interface gonflable (16) comprend une matière élastomère.

9. Sonde intracavitaire introductible selon l'une quelconque des revendications 1 à 8,
caractérisée en ce que:
- ledit moyen formant ballonnet d'interface (16) comprend un organe non extensible (50) pour positionner ladite bobine réceptrice (52) dans ledit moyen formant ballonnet d'interface (16).

10. Sonde intracavitaire introductible selon l'une quelconque des revendications 1 à 9,
caractérisée en ce que:
- ledit organe allongé en forme de tige (14) a au moins un passage, ledit moyen de gonflage (24) est connecté audit organe en forme de tige (14) et connectés audit moyen formant ballonnet d'interface gonflable (16) par l'intermédiaire dudit passage dudit organe en forme de tige (14); et
- ledit câble d'interconnexion (30) est connecté audit organe en forme de tige (14) pour réaliser une connexion électrique à ladite bobine réceptrice flexible (52) par l'intermédiaire dudit passage dudit organe en forme de tige (14).

11. Sonde intracavitaire introductible selon l'une quelconque des revendications 1 à 10,
caractérisée en ce que:
- ledit organe allongé en forme de tige (14) comporte des premier (48) et deuxième (54) passages, ledit moyen de gonflage est connecté audit ballonnet gonflable par l'intermédiaire dudit premier passage (48) dudit organe en forme de tige (14); et
- ledit câble d'interconnexion (30) est connecté à ladite bobine réceptrice flexible (52) par l'intermédiaire du deuxième passage (54) dudit organe en forme de tige (14).

12. Sonde intracavitaire introductible selon l'une quelconque des revendications 9 à 11,
caractérisée en ce que:
- ledit organe non extensible (50) est attaché à la surface dudit ballonnet intérieur (44) en position contiguë à ladite bobine réceptrice (52).

13. Sonde intracavitaire introductible selon la revendication 11 ou 12,
caractérisée en ce que:
- ledit moyen de gonflage comprend un coussin gonfleur compressible (24) et un tube (26) connecté audit organe en forme de tige (14) pour délivrer de l'air, lors de la compression dudit coussin (24), audit ballonnet intérieur (44) par l'intermédiaire dudit passage (48) dudit organe en forme de tige (14), et comprenant en outre un robinet d'arrêt (28) sur le tube (26) connectant ledit coussin gonfleur (24) audit organe en forme de tige (14), ledit robinet d'arrêt (28) maintenant ledit ballonnet intérieur (44) dans un état gonflé lorsqu'il est placé dans une position de fermeture.

14. Sonde intracavitaire introductible selon l'une quelconque des revendications 1 à 13,
caractérisée en ce que:
- ladite bobine réceptrice flexible (52) est une bobine résonnante série, et ledit câble d'interconnexion (30) est un câble quart d'onde qui transforme la bobine résonnante série en une bobine résonnante parallèle vue de l'extrémité proximale du câble.

15. Sonde intracavitaire introductible selon l'une quelconque des revendications 2 à 14,
caractérisé en ce que:
- ledit ballonnet extérieur (46) comprend une forme antérieure en selle (62) sur une surface de celui-ci et des renfoncements (74) de chaque côté dudit ballonnet extérieur (46); et
- ladite bobine réceptrice flexible (52) contenue à l'intérieur dudit moyen formant ballonnet d'interface (16) entre ledit ballonnet intérieur (44) et ledit ballonnet extérieur (46) est maintenu en position dans ledit moyen formant ballonnet d'interface (16) par lesdits renfoncements latéraux (74) dudit ballonnet extérieur (46).

16. Sonde intracavitaire introductible selon l'une quelconque des revendications 10 à 15,
caractérisée en ce que:
- ladite bobine réceptrice flexible (52) et ledit câble d'interconnexion (30) sont formés d'une seule et même longueur de câble coaxial pour hautes fréquences;
- ledit moyen de gonflage (24) est connecté audit organe en forme de tige (14) et connecté audit moyen formant ballonnet d'interface gonflable (16) par l'intermé-

diaire dudit passage dudit organe en forme de tige (14); et

- ledit câble d'interconnexion (30) est connecté audit organe en forme de tige (14) pour réaliser une connexion électrique à ladite bobine réceptrice flexible (52) par l'intermédiaire dudit passage dudit organe en forme de tige (14).

17. Sonde intracavitaire introductible selon l'une quelconque des revendications précédentes, caractérisée en ce que:

- ledit organe allongé en forme de tige (14) comprend une partie allongée rigide et une partie extrême distale flexible (15).

18. Sonde intracavitaire introductible selon l'une quelconque des revendications précédentes, caractérisée en ce que:

- la sonde comprend en outre une poignée (22) à l'extrémité proximale dudit organe en forme de tige (14),
- dans laquelle ledit organe en forme de tige (14), ledit moyen formant ballonnet d'interface (16) et ladite poignée (22) sont joints ensemble pour tourner d'une seule pièce lorsqu'un couple est appliqué à ladite poignée (22).

19. Sonde intracavitaire introductible selon l'une quelconque des revendications précédentes, caractérisée en ce que:

- la sonde comprend en outre un moyen formant marque d'alignement sur ledit organe en forme de tige (14) pour indiquer la position longitudinale et radiale relative dudit organe en forme de tige (14) lorsqu'elle est est introduite dans un patient.

20. Sonde intracavitaire introductible selon l'une quelconque des revendications précédentes, caractérisée en ce que:

- ledit organe en forme de tige (14) comporte une échelle de positionnement imprimée sur la surface extérieure de celui-ci.

21. Sonde intracavitaire introductible selon l'une quelconque des revendications précédentes, caractérisée en ce que:

- la sonde comprend un disque antimigration (18), ledit disque antimigration (18) ayant une forme hémisphérique et une fente qui s'encliquète sur ledit organe en forme de tige (14) pour empêcher un mouvement indésirable de ladite sonde (10) par rapport à la cavité du patient.

22. Sonde intracavitaire introductible selon l'une quelconque des revendications précédentes, caractérisée en ce que

la sonde comprend un élément dilateur monté coulissant sur ledit organe en forme de tige (14) pour dilater un orifice conduisant à ladite cavité pour permettre le positionnement aisé de la sonde (10) à l'intérieur de la cavité.

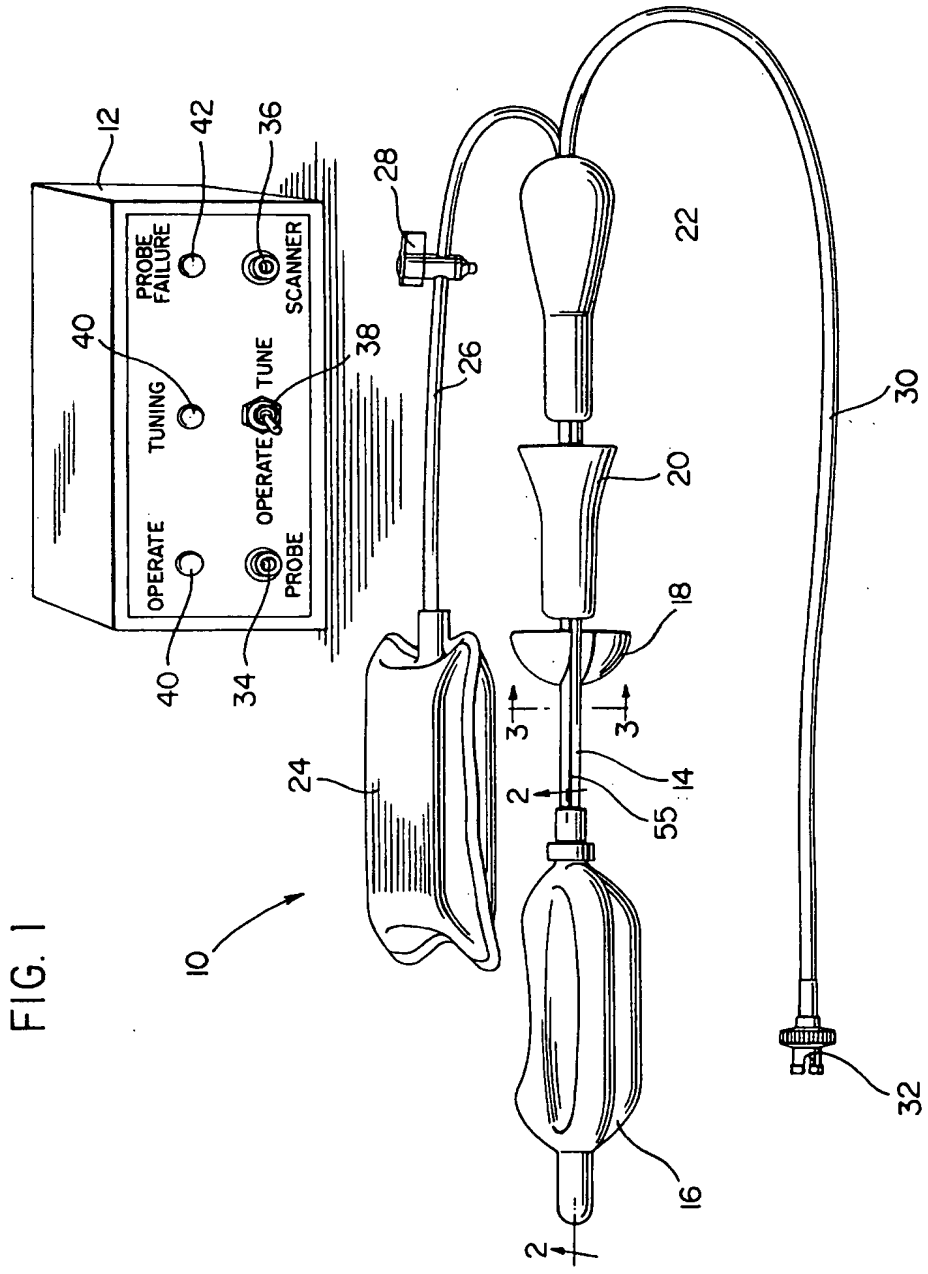

12
42
36
28
22
PROBE FAILURE
SCANNER
40
TUNING
38
TUNE
26
30
OPERATE
OPERATE
PROBE
20
18
40
34
3
3
24
2
14
55
10
16
2
32

FIG. 1

FIG. 2

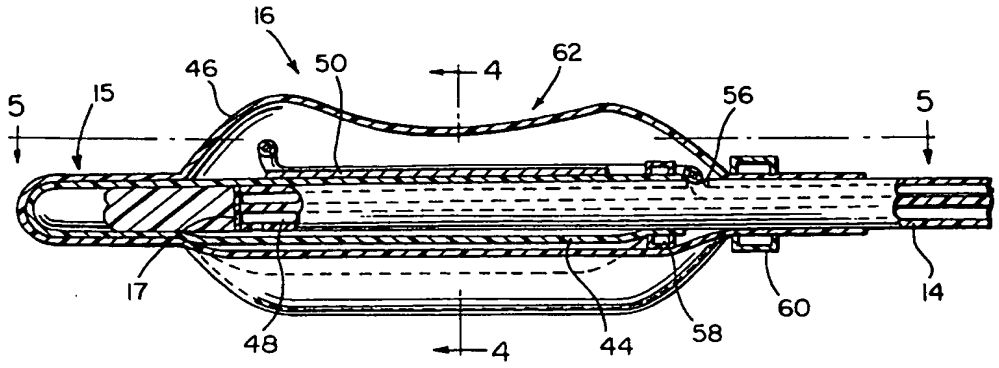


FIG. 3

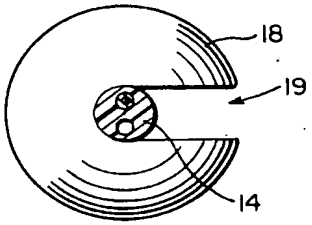


FIG. 4

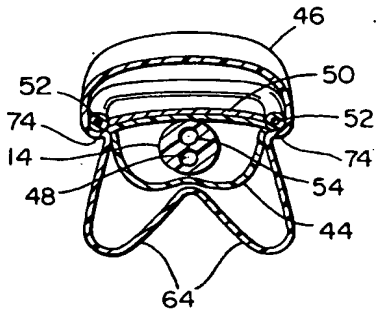


FIG. 5

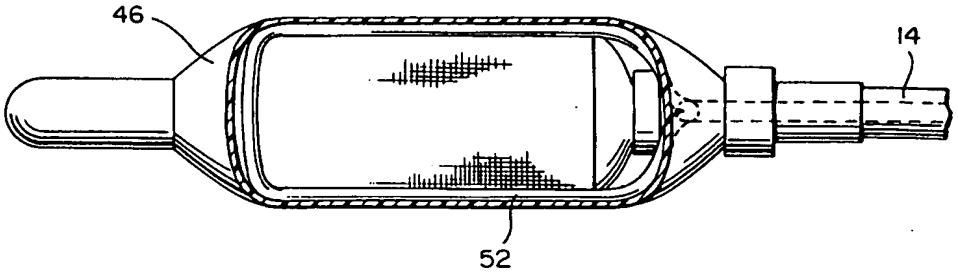


FIG. 6

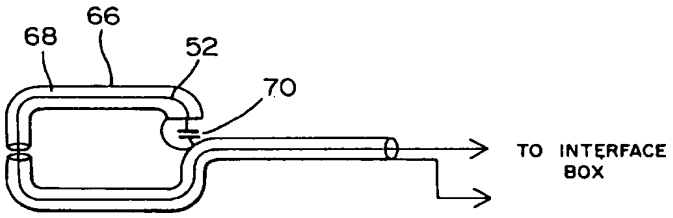


FIG. 7

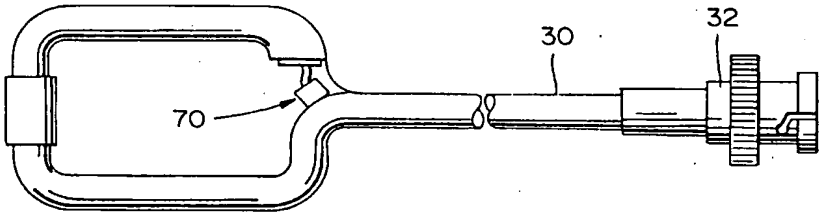


FIG. 8

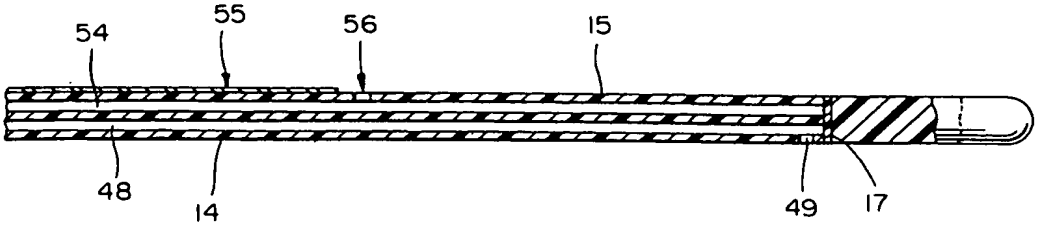


FIG.9

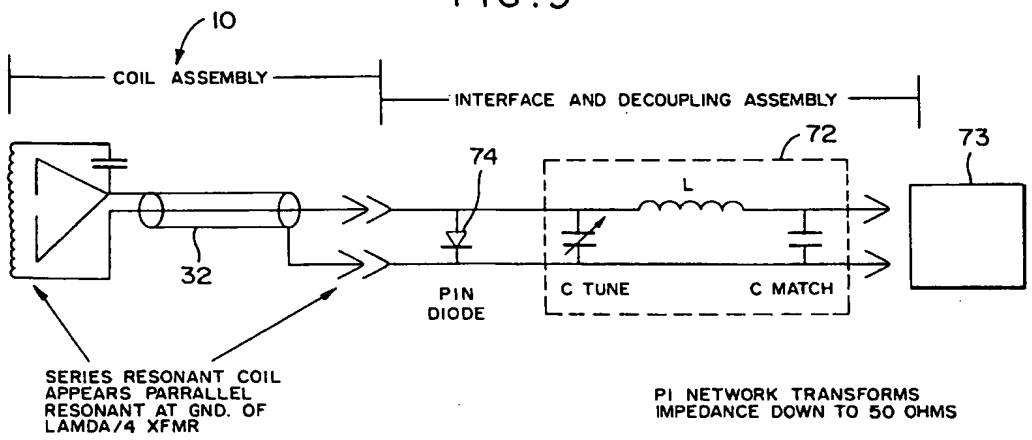

10
COIL ASSEMBLY
INTERFACE AND DECOUPLING ASSEMBLY
72
73
74
L
32
PIN DIODE
C TUNE
C MATCH
SERIES RESONANT COIL APPEARS PARRALLEL RESONANT AT GND. OF LAMDA/4 XFMR
PI NETWORK TRANSFORMS IMPEDANCE DOWN TO 50 OHMS

FIG.11

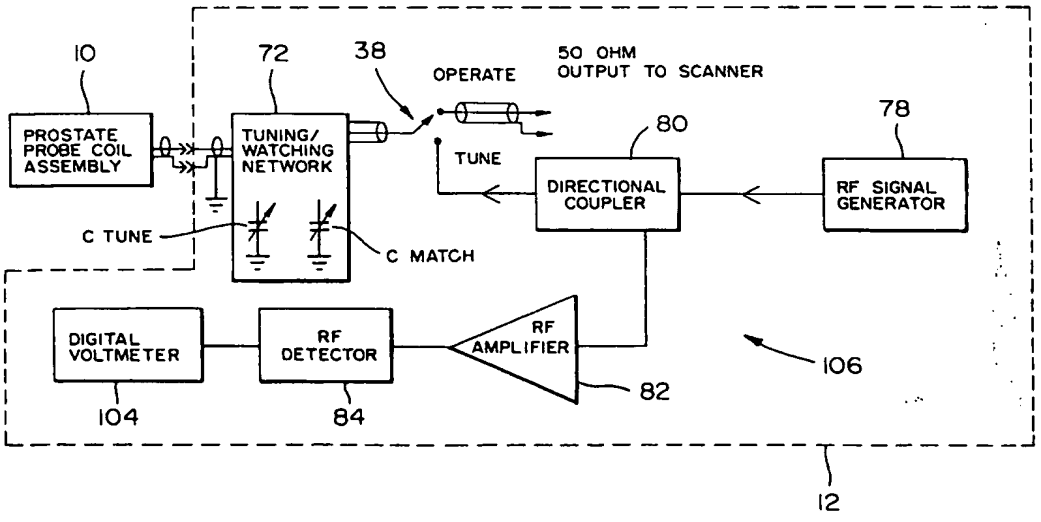
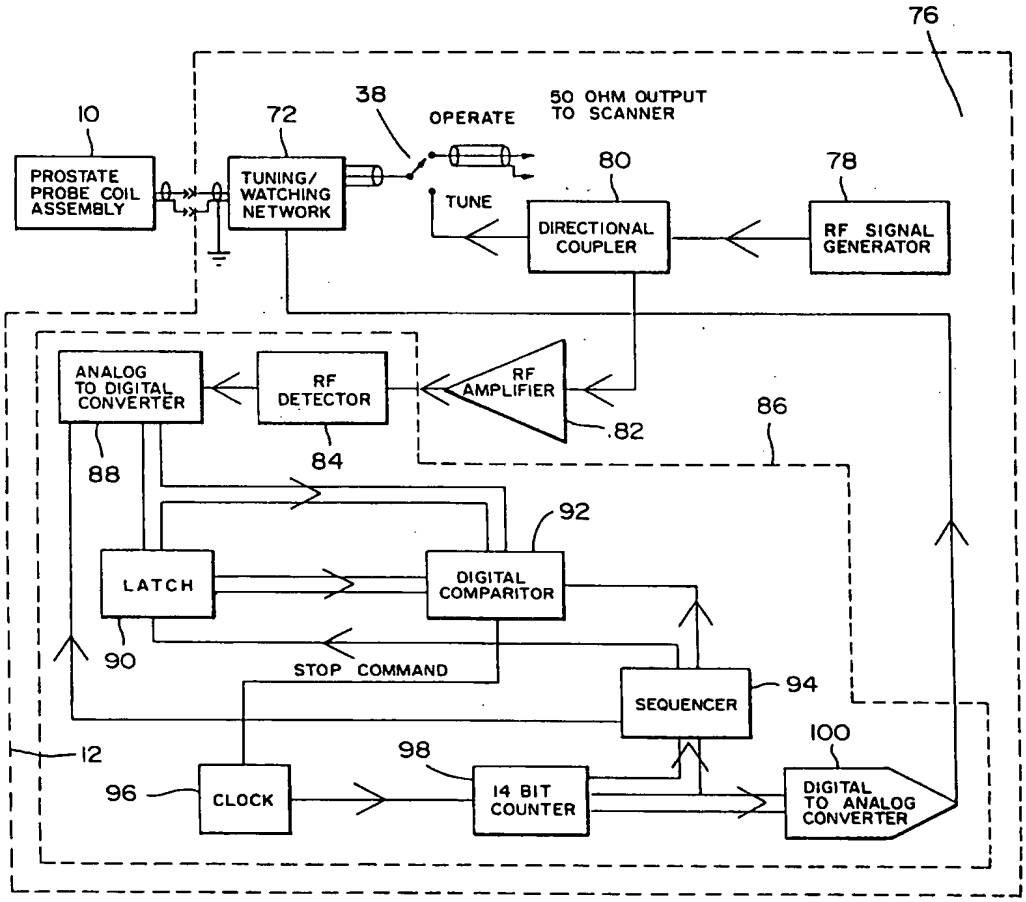

10
72
38
OPERATE
50 OHM OUTPUT TO SCANNER
78
80
PROSTATE PROBE COIL ASSEMBLY
TUNING/ WATCHING NETWORK
TUNE
DIRECTIONAL COUPLER
RF SIGNAL GENERATOR
C TUNE
C MATCH
DIGITAL VOLTMETER
RF DETECTOR
RF AMPLIFIER
106
82
104
84
12

FIG. 10


76
10
PROSTATE PROBE COIL ASSEMBLY
72
TUNING/ WATCHING NETWORK
38
OPERATE
TUNE
50 OHM OUTPUT TO SCANNER
80
DIRECTIONAL COUPLER
78
RF SIGNAL GENERATOR
ANALOG TO DIGITAL CONVERTER
RF DETECTOR
RF AMPLIFIER
82
86
88
84
92
LATCH
DIGITAL COMPARITOR
90
STOP COMMAND
94
SEQUENCER
100
12
98
96
CLOCK
14 BIT COUNTER
DIGITAL TO ANALOG CONVERTER